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ABSTRACT

This paper reports on a research study examining the benefits of investigations as non-traditional assessment tasks in the lower secondary school. A mathematical investigation is defined as an inquiry into a mathematical situation, the topic of which may arise from real life or a mathematically designed problem. Students are required to apply familiar skills and concepts to the unfamiliar situation of the investigation. In this study, the investigations used were assessment items that were part of the normal school program. Four teachers and 18 students participated in the study. The main methods of data collection were interviews and observations. Both teachers and students participated in the interviews. The observations, however, were more focused on the students. Student journal writing, related documents and artifacts, and student samples supplemented this data. The major findings from the study were that the investigations enabled students to learn more effectively, to become more involved in mathematics at school, and to interact more frequently with each other. Specific findings from the interviews revealed that students felt more challenged in mathematics and developed a greater understanding of the concepts involved. The observations were consistent with the interviews and showed students actively engaging themselves in the mathematical processes of the investigation. (Author/ASK)

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Benefits of investigations as non-traditional assessments in secondary mathematics.

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Abstract

This paper reports a research study examining the benefits of investigations as non-traditional assessment tasks in the lower secondary school. A mathematical investigation is defined as an inquiry into a mathematical situation, the topic of which may arise from real life or a mathematically designed problem. Students are required to apply familiar skills and concepts, to the unfamiliar situation of the investigation (Reid and Wright, 1994). In this study, the investigations used were assessment items that were part of the normal school program. Four teachers and 18 students participated in the study. The main methods of data collection were interviews and observations. Both teachers and students participated in the interviews. The observations, however, were more focused on the students. Student journal writing, related documents and artefacts, and student samples supplemented this data. The major findings for the study were that investigations enabled students to learn more effectively, to become more involved in mathematics at school, and to interact more frequently with each other. Specific findings from the interviews revealed that students felt more challenged in mathematics, and developed a greater understanding of the concepts involved. The observations were consistent with the interviews, and showed students actively engaging themselves in the mathematical processes of the investigation.

Introduction

This paper reports a preliminary study that examined the role of investigations in the teaching, learning and assessment of mathematics in the secondary school. As the study unfolded, particular interest was directed towards the role of mathematical investigations as assessment tasks. Some of the main project aims were to document, describe and analyse the variety of ways in which students engaged in the process of mathematical investigations, and to provide a 'window' on teachers' and students' views of what really goes on during the processes of a mathematical investigation. Investigations are highly recommended by various policy and curriculum documents at state, national and international levels. They are examples of rich learning tasks, in which students learn and develop basic knowledge and skills that are relevant to real life situations. For example, Education Queensland have developed and designed 'rich learning tasks' for students to develop knowledge and skills associated with the 'new basics'. The 'new basics' include considerations of: Life Pathways and Social Futures; Multiliteracies, Numeracy and Communication Media; Active citizenship and; Environments and Technology. Such tasks pose a challenge for students, and require them to think deeply and critically about what they are expected to do. These tasks also provide opportunities for students to discuss the work with their peers and construct self-help groups, especially in situations where the teacher may be too busy to help each and every individual. If 'rich learning tasks' are to be included in the curriculum, then it should follow that 'rich assessment tasks' should also be included to reflect the current goals of schooling. Rich assessment tasks are a reflection of what has been taught, and encourage students to show connections that they are able to make between the concepts that they have learned (Clarke & Clarke, 1999). The paper also endeavoured to examine whether these investigations promoted joint problem-solving, whether the students organised their own self-help groups, and if these were effective means of working together to construct their own knowledge, or focus solely on getting the right answer.

Theoretical basis

Investigations

Jaworski (1994) introduces mathematical investigations, in a broader discussion of an investigative approach to mathematical teaching. Mathematics investigations involves students addressing loosely defined problems, and being guided to follow their own interests and inclinations, setting their own goals, doing their own mathematics and moreover, being motivated to do these tasks (Jaworski, 1994). While these are ideal outcomes of an investigation, it may be a problematic view as in practice, students may be given little choice in the problems that they have to do, because everyone else is doing it. They may learn something from it, but still may not necessarily develop a positive attitude towards engagement in their mathematics. Jaworski suggests that one of the reasons for including investigations is that they promote the development of mathematical processes which can be applied in other mathematical work. Jaworski goes on further to say that investigative work encourages a critical construction of knowledge, as well mathematical exploration, enquiry and discovery on the part of the student.

Bishop (1988) advocates the use of investigations to diversify students' learning experiences in order "to create curricular structures which allow individuality to be experienced" (p.97). Investigations, which are extended pieces of work undertaken individually (or in small groups, like projects), involve two distinct phases: firstly, the creative and inventive phase when the mathematical ideas are being explored, analysed and developed; and the second phase, which involves one writing a report on the activity in the first phase. While Bishop provides a clear definition of what an investigation entails, his emphasis on the individual is problematic, as there are possibilities that the first phase of the investigation could have involved some form of collaborative learning.

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Social Constructivism

The theoretical orientation that underpins the research on the notion of the investigation is the social constructivist theory. This theory is understood by Simon (1995) as the "co-ordination of psychological and sociological analyses of learning". This theory views mathematical learning as a social construction of knowledge from shared meanings (Ernest, 1991). Both the constructivist and sociocultural theories are considered for review, because their basic principles provide a foundation for understanding the relationship between learning and thinking processes as well as the communicative processes that constitute the learning and problem-solving processes. This, however, poses a debate as to whether the mind is located in the head or in individual-in-social actions, especially in the course of an investigation. Galbraith et al (1999) make a clear distinction between the sociocultural and constructivist positions. A sociocultural orientation views learning as "a collective process of enculturation into practices of mathematical communities", while the constructivist position gives priority to the individual construction of understanding. With the constructivist position, "social interaction acts as a source of cognitive conflict to force the reorganisation of personal metnal structures".

Cobb (1994) argues that the learning involved in mathematical activity should be viewed as a process of both active individual construction and process of enculturation. This argument is based on his acknowledgement of the considerable debate on whether mind can be conceptualised in the head or in the individual-in-social action. Rather than adjudicating a dispute between the opposing perspectives, he attempts to co-ordinate the constructivist and sociocultural perspectives in mathematics education. An important point that Cobb raises is that both both the constructivist and sociocultural perspectives highlighted the important role of activities in mathematical learning and development, although the two perspectives offer contrasting explanations. From a sociocultural perspective, an individual participating in an investigation would gain a greater understanding of their thinking processes after interacting socially with others, and working with others to complete the investigation. Vygotsky's notion of the zone of proximal development provides an important basis for understanding the possible benefits of social interactions in the classroom. The zone of proximal development is defined as the distance between a child's actual development as determined by individual problem-solving", and the higher level of "potential development" as determined through problem solving under adult guidance or in collaboration with more "capable peers" (Wertsch, 1991). During investigations, students do gather their knowledge and understanding of the concepts, not just by the hands-on experience, but the experience of being able to negotiate the task requirements with their peers and the expert teacher. From participating in these zones of proximal development with the teacher and their peers, they are then able to internalise and transform the learning material into something that has personal relevance and meaning.

Methodology

The data that I am reporting on here, is drawn from a preliminary study conducted with several case study classes at a public secondary school in the western outskirts of Brisbane. This school was chosen for the study, because of the Head Mathematics teacher's interest in promoting non-traditional assessment in mathematics. The investigation took place at the time, when all Year 8 and Year 9 classes were doing their investigations and practical hands-on assignments. This was arranged, so that the researcher would be there at a time coincidental to when the teachers were doing the investigation work with the students, so as not to disrupt too much teaching and learning time.To collect data, I used observations and interviews. I even attempted using journals to find out students' views of the processes that they engaged in, during the investigations. The participants were teachers and students from two Year 8 and two Year 9 classes.

In the words of the two teachers, Reid and Wright (1992), a mathematical investigation is:

> *"...an inquiry into a mathematical situation, the topic of which may arise from real life, or from a mathematically designed problem. Students are required to apply familiar skills and concepts to the unfamiliar situation of the investigation and communicate their findings in a report."*

Reid and Wright incorporate the two phases of an investigation, as described by Bishop (1988). Unlike Bishop, they go on to include investigations as part of the assessment program in the mathematics curriculum at the school. In a program that they proposed, they anticipated that by incorporating an investigative maths program into the mathematics program at this particular school, students will gain:

- A willingness to attempt, explore and extend unfamiliar problems;
- A flexibility in approaching mathematical problems;
- Enhanced ability to draw on mathematical knowledge;
- Enhanced ability to communicate mathematical information in both written and oral form;
- Improved skills in empirical testing and algebraic validation; and
- Skills in group work

It is anticipated that as my study will be conducted in this particular school, where they are conducting this particular program,

that some of the outcomes from the study, meet the goals that have been listed above.

The Year 8 students completed the Basketball Court Assignment (attached). The concepts involved were measuring length and area. This assignment involved students working in pairs or groups, to state the length of their pace, measure the length, and width of the entire basketball court, as well as the minor dimensions, such as the radius centre circle and of the free-throw area. The students were required to work together to gather their data, and to produce their own calculations. They were also given the opportunity to go out onto the basketball courts, to collect their data there. This assignment was broken up into Core and Extension activities. Whilst the Core questions required students to simply state the measurements they took while on the basketball courts, the Extension questions required the students to use the measurements they acquired and apply these to questions that required them to find or calculate the area of certain parts of the basketball courts.

The Year 9 students completed the assignment on Measuring Heights (attached). Their task was to calculate the height of an object within the school grounds using two different methods. They had to work to work in pairs or groups to measure an object of their choice, whether it be a tree, a building or a shed. The students were also required to use measuring instruments such as a clinometer or a mirror. The concepts involved trigonometry and similar triangles.

Findings

From the range of data provided by students and teachers, three major themes emerged: 1) Students experienced meaningful learning; 2) Students became involved in their own learning process; and 3) Students interacted with each other.The findings of the study revealed that investigations, as non-traditional assessments, proved to be beneficial for students. It opened up opportunities for understanding relevant mathematical concepts. Empirical verification shows that within the themes, some of the goals for the investigative maths program incited by Reid and Wright, were able to be achieved.

The students experienced meaningful learning. Student anecdotes revealed that they experienced meaningful learning by participating in these tasks. In doing investigations, they were able to cover a particular mathematics topic in greater detail, and were challenged to think for themselves. This was particularly evident in one students' comment.

> *Just, um, how they give... like it's not the same work, like there's no basic real answers to them. You just got to like, try and figure them out and hope for the best. You just can't cheat and that. They give you like ... They make you work pretty hard, and gives your brain a test. [SM9: 12]*

What this student means is that you can't avoid engagement in the task by just looking for the answer at the back of the textbook. You have to be able to work things out and hope that you're on the right track and doing it the right way. Situations like this, discourages students from attempting to find the right answer and thus, forces one to think for oneself and test the power of their thinking. This student's comment was also supported by another student, who felt more challenged to do different things, apart from just exercises in the book.

> *Yeah, because it helps you to build up your courage and all that, to learn how to do more things. [ST8:16]*

"Courage" here, conveys the idea that the exposure to different ways of doing things, other than just learning from teacher chalk-and-talk, and textbook exercises, enabled this student to gain more confidence in doing hands-on activities, like going out of the classroom to measure a basketball court, using measuring devices or a trundle wheel or a tape measure. The previous comment also provided evidence that the students were able to demonstrate a flexibility in approaching mathematical problems, after being given the opportunity to do so. These comments by students were also evidence of their willingness to attempt, explore and extend unfamiliar problems. Other students also claimed that the investigations gave them more opportunities to learn about a particular topic in greater detail.

> *Learning more about each topic, like if we were doing measurements like the basketball court, like we learn how to take measurements, and like how to do paces and metres. Yeah, so stuff like that [SA8:38].*

> *I understood the tangent much better, like in the way we added it up and that. I understood it more than what I did in class, because we did it in further detail. [ST9:44]*

The statements provided by these two students suggest that these practical hands-on tasks assisted them to gain a deeper understanding of the concept, by seeing it work in practice. By measuring a basketball court with the appropriate tools, SA8 was able to understand and appreciate the methods of measurements, and how the concepts of pace and metres were associated with the measurements. ST9 also learnt more about the tangent rule, by having to measure the height of an object that is over 2 metres high, with the clinometer. By using a clinometer, she was able to gain a greater understanding of how the tangent rule was to be used. However, rather than drawing on mathematical knowledge, as was one of the goals in the program, students were able to enrich their mathematical knowledge after participating in the investigation.

Students were engaged in their own learning. The nature of the tasks encouraged students to be more engaged in the work. It was observed that students were willing to work together to accomplish a goal and to finish a task successfully. They also showed enthusiasm about having to work on their own, and to establish an understanding of the concepts through their

own experiences. This was reflected in the words of one student who believed such experiences aided in later recall of the concepts used.

> *"...Yeah a better idea of doing it, and you actually remember. When you're just sitting there, with the textbook, it just goes in one ear and straight out the other (laughs).[SJ9: 9]"*

This student suggests that participating in the investigations was conducive to alternative representations of heights and tangents. If she had only seen an example in the textbook, the representation would have little meaning for her. Seeing how the tangent could be used in real life was most helpful, as it aided her understanding and her ability to remember.

This picture also shows how students were engaged in their work. The investigation opened up opportunities for them to experience hands-on, the methods of measuring the height of an object that appeared to be over 2m. The students in this particular class were very involved, taking different roles to measure the distance from the tree to the point where they would attempt to measure the height of the tree. While one student measured out the required 15m, another student measured the eye height of her peer, and the student whose height was being measured, used the clinometer to measure the angle of elevation. The learning that was involved here promoted students' abilities to work in groups and to gain flexibility.

Students interacted with each other. By interacting more with each other, students were able to develop their skills in group work. In one lesson, it was observed that students actively negotiated the task together and were helping with different aspects of the practical tasks. While one student used the instruments, the other students looked on, to announce the measurements they achieved. Students were enthusiastic about working with their peers, because they felt that they could help each other out, and did not feel so apprehensive about having to ask their teacher. One student's comment illustrates this.

> *Yeah, because ... like you're there with friends, and you can work together on it. If you got something wrong, they could tell you, and like, you could help each other out. [SC9:10]*

Sometimes students also felt that they learnt better through interacting with each other. This was because they were able to understand the explanations used by their peers, better than those used by their teachers.

> *Yeah, it helped a lot, once I've had it explained, because sometimes when you're listening to Ms Fuller, she sometimes explains things, and then you won't get it; when she goes back, you still sometimes don't get it. But when you're listening to someone, same age as us, they explain it in our terms. [SK9:24]*

This student's comment was supported by her teachers' comment that students do learn better from each other by talking in a language that they understood best. The teacher later illustrated this in a comment that was made, when perusing through one of the student journals.

> *"...K's made a comment here, where she says...I'm sorry, not K, C has made a comment here, that K asked her, whether she could explain how to do the working of the triangles, and C says she enjoys helping her classmates, because it not only helps her look smart, joke in brackets, but it also helps her understand when she explains it in her terms. I'd really put it through experience, that it's a very valid comment, because it does help her to explain, it does help her to understand, when she explains, but that's not such a joke either, about it making her look smart, it does really build self-esteem and confidence, to be able to help other students. That's very very important." [F9:22]*

This comment by the teacher showed that she supported the fact that students interacted with each other, as it also gave them opportunities to explain to each other how to do things, and to boost their own understanding and self-confidence in mathematics. Furthermore, the experience of writing the journal contributed to the metacognitive knowledge of students, as well as expressing the boost in their self-esteem. This is an interesting finding which would be worth exploring in further depth.

Other notable findings.

Other notable findings from the preliminary study were factors that helped or hindered learning during these investigations. Some of the factors that helped students with these investigations were teachers preparing the students by giving clear explanations about approaching the task, and the opportunities to seek assistance from other students. Some possible hindrances to student learning were student misbehaviour and negative attitudes to learning mathematics. One teacher commented

> *"...as soon as they get outside the classroom, the kids start to get a bit ballistic [M8: 6].... I've tried it a couple of times with kids before, and I've found that they've got too agitated doing anything outside the classroom [M8:10]"*

Fear of misbehaviour remains a crucial impediment for some teachers in implementing more active teaching and learning strategies. Teachers who lack the confidence or the will to engage in learning activities outside the classroom, are likely to limit students' opportunities to build richer and more diverse representations of mathematical concepts.

Conclusions

It is to be recalled that the aims of the study were to document, describe and analyse the variety of ways in which students engaged in the process of mathematical investigations, and provide a window to teacher's and students' views of the processes involved in these mathematical investigations. The main findings from this study were that students experienced active learning, were engaged in the learning process and interacted with each other. Within each theme, the data from observations and interviews with teachers and students sometimes challenged and supported the theory that was offered on investigations and social constructivism. Observations of the lessons were inconsistent with the suggestions offered by Jaworski (1994). While Jaworski suggested that mathematical investigations involved students addressing loosely defined problems, and guided them to follow their own interests, observations in this study revealed that the investigations being administered to students were tightly structured, and students did not have the choice to choose to follow their own topic of interest. Even though these were more tightly structured, nonetheless students anecdotes and observations did reveal that they had opportunities to construct their own knowledge of the relevant concepts by exploring, enquiring and discovering ways and means of measuring a basketball court or measuring the height of a building. Opportunities to interact with each other enabled students to learn and to understand the concepts. Student's reflections of understanding their peers' explanations supported the principles of social constructivism, which views learning as a social construction of knowledge from shared meanings (Ernest, 1991). The data collection methods (interviews and observations) that were used were adequate, although means to capture meaningful dialogue to further enrich data, are needed.

This preliminary study was the stepping stone for my current study, which focuses on the ways that students interact and help each other during these investigations. My current study "Who Helps You?" is an attempt to trace the complex network of collaborations that support students in their learning activities.

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